High airway and alveolar pressures

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OVERVIEW

High airway pressures are important because they may:

have adverse effects on the patient

indicate a deterioration of the patient's condition

indicate an equipment problem that needs to be addressed

It is important to distinguish between airway pressure and alveolar pressure

AIRWAY PRESSURE AND ALVEOLAR PRESSURE

Airway pressure

airway pressure = flow x resistance + alveolar pressure

Thus if flow or resistance is markedly altered, a change in airway pressure will *not* be indicative of a change in the alveolar pressure

Airway pressure is more conveniently measured than alveolar pressure

Peak inspiratory pressure (PIP) is displayed on most ventilators

A maximum acceptable PIP of <35 cmH20 is widely used

Alveolar pressure

Alveolar pressure is estimated by determining the inspiratory pause pressure, which corresponds to the plateau pressure

The inspiratory pause pressure is determined by observing the plateau pressure in an apneic ventilated patient when when the '*inspiratory pause hold*' control is activated

Because flow is reduced to zero, airway pressure and alveolar pressures will equalise and the airway pressure will correspond to the alveolar pressure at full inspiration

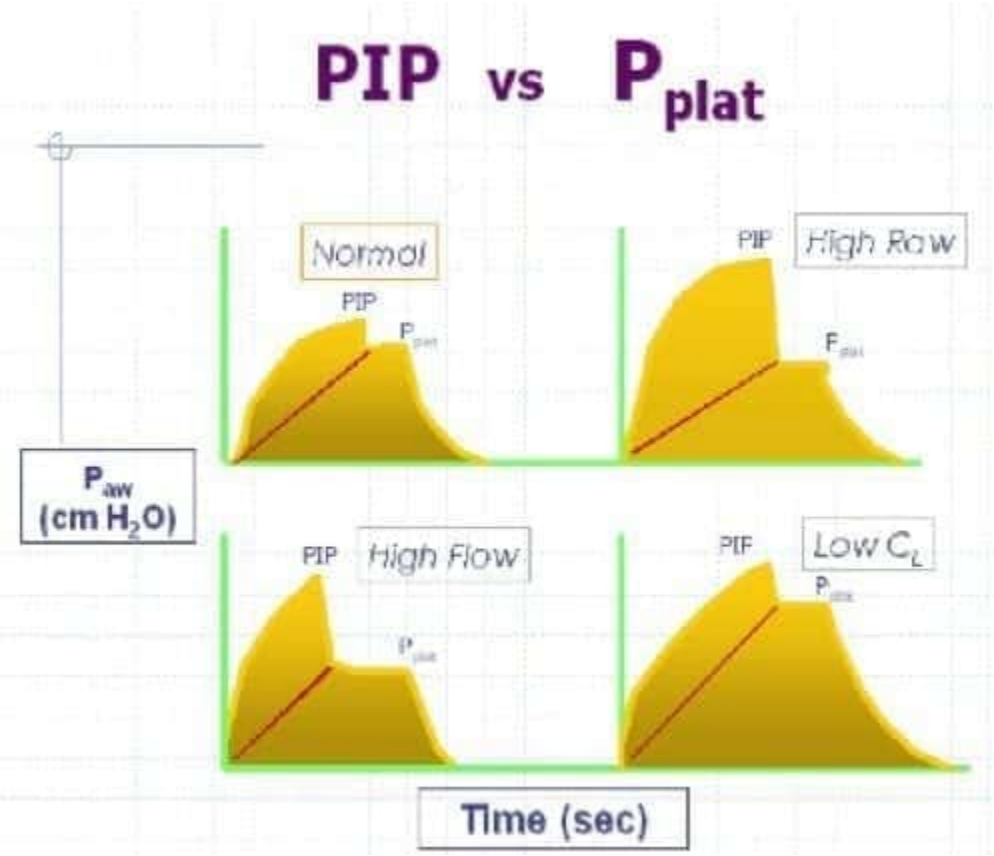
airway pressure = 0 x resistance + alveolar pressure = alveolar pressure

To prevent lung injury, alveolar pressure (aka the plateau pressure) should be kept <30 cmH2O

High alveolar pressures can be due to excessive tidal volume, gas trapping, PEEP or low compliance as shown by this relationship:

alveolar pressure = (volume/ compliance) + PEEP

PRESSURE-TIME CURVES SHOWING PIP AND PLATEAU PRESSURES IN VOLUME CONTROL VENTILATION



Normal curve – demonstrates normal PIP , Pplat , PTA (transairway pressure), and Ti (inspiratory time). High Raw curve – A significant increase in the PTA is associated with increased airway resistance. High Flow curve – the inspiratory time is shorter than normal, indicating a higher inspiratory gas flow rate. Decreased Lung Compliance curve – An increase in the plateau pressure and a corresponding increase in the PIP is consistent with decreased lung compliance.

EFFECTS OF HIGH PRESSURES

High airway pressure is not necessarily harmful, unless it reflects high alveolar pressure which can have these effects:

barotrauma may result in acute lung injury (leading to ARDS) or air leaks (e.g. pneumothorax, pneumomediastinum)

Excessive intrathoracic pressure may also result, with potential hemodynamic consequences (particularly decreased venous return, leading to hypotension and potentially cardiac arrest)

High airway pressures may result in inadequate ventilation

Ventilator response to high airway pressures:

Inadequate ventilation can occur because many ventilators are set to terminate the inspiratory flow if the upper pressure limit setting is reached. When this occurs inspiratory volumes are markedly reduced, resulting in low tidal volumes and minute ventilation

Other ventilators do not do this but will simply hold the airway pressure at the pressure limit, resulting in a smaller reduction in tidal volume

There many also be other consequences of the underlying cause

CAUSES OF HIGH PRESSURES

Think “Man versus machine”

First, let’s consider the machine:

Ventilator
inappropriate settings

ventilator malfunction

Circuit
kinking

pooling of condensed water vapour

wet filters causing increased resistance

Endotracheal tube
displacement, e.g. endobronchial intubation

kinking

obstruction with foreign material

And now the man:

bronchospasm (e.g. asthma)

decreased compliance

lung (e.g. collapse, consolidation, pulmonary edema, ARDS)

pleural (e.g. pneumothorax, pleural effusion)

chest wall (e.g. abdominal distention, kyhposcoliosis, obesity)

patient-ventilator dysynchrony, coughing

APPROACH TO PATIENT WITH HIGH AIRWAY PRESSURES

Disconnect the patient from the ventilator and manually bag the patient using high-flow oxygen and bag-valve-mask

While the patient is disconnected from the ventilator assess the “feel” of the lungs while bagging:
If the patient is not difficult to ventilate then the problem is with the ventilator or the circuit

If the patient is difficult to ventilate it is a problem with the endotracheal tube or the respiratory system

For ventilator and circuit problems:
check the ventilator settings that it is functioning correctly (e.g. on a test lung)

check the circuit for obstruction or kinking

For patient or ETT problems:
examine the patient looking for:
wheeze

asymmetrical chest expansion

evidence of collapse

evidence of dyssynchrony

Pass a suction catheter through the ETT to check its patency

Use ETCO2 and perform a CXR to check ETT position and look for potential causes of decreased compliance

If the cause is still not clear measure inspiratory pause pressure to estimate alveolar pressure, in addition to the peak inspiratory pressure that reflects airway pressure.

If both airway and alveolar pressure are high the problem is due to poor compliance (e.g. pulmonary edema)

If only the airway pressure is high the problem is one of high resistance (e.g. bronchospasm)

Seek and treat underlying causes

References and Links

CCC Ventilation Series

Modes: Adaptive Support Ventilation (ASV), Airway Pressure Release Ventilation (APRV), High Frequency Oscillation Ventilation (HFOV), High Frequency Ventilation (HFV), Modes of ventilation, Non-Invasive Ventilation (NIV), Spontaneous breathing and mechanical ventilation
Conditions: Acute Respiratory Distress Syndrome (ARDS), ARDS Definitions, ARDS Literature Summaries, Asthma, Bronchopleural Fistula, Burns, Oxygenation and Ventilation, COPD, Haemoptysis, Improving Oxygenation in ARDS, NIV and Asthma, NIV and the Critically Ill, Ventilator Induced Lung Injury (VILI), Volutrauma
Strategies: ARDSnet Ventilation, Open lung approach, Oxygen Saturation Targets, Protective Lung Ventilation, Recruitment manoeuvres in ARDS, Sedation pauses, Selective Lung Ventilation
Adjuncts: Adjunctive Respiratory Therapies, ECMO Overview, Heliox, Neuromuscular blockade in ARDS, Prone positioning and Mechanical Ventilation
Situations: Cuff leak, Difficulty weaning, High Airway Pressures, Post-Intubation Care, Post-intubation hypoxia
Troubleshooting: Autotriggering of the ventilator, High airway and alveolar pressures / pressure alarm, Ventilator Dyssynchrony
Investigation / Indices: A-a gradient, Capnography and waveforms, Electrical Impedance Tomography, Indices that predict difficult weaning, PaO2/FiO2 Ratio (PF), Transpulmonary pressure (TPP)
Extubation: Cuff Leak Test, Extubation Assessment in ED, Extubation Assessment in ICU, NIV for weaning, Post-Extubation Stridor, Spontaneous breathing trial, Unplanned extubation, Weaning from mechanical ventilation
Core Knowledge: Basics of Mechanical Ventilation, Driving Pressure, Dynamic pressure-volume loops, flow versus time graph, flow volume loops, Indications and complications, Intrinsic PEEP (autoPEEP), Oxygen Haemoglobin Dissociation Curve, Positive End Expiratory Pressure (PEEP), Pulmonary Mechanics, Pressure Vs Time Graph, Pressure vs Volume Loop, Setting up a ventilator, Ventilator waveform analysis, Volume vs time graph
Equipment: Capnography and CO2 Detector, Heat and Moisture Exchanger (HME), Ideal helicopter ventilator, Wet Circuit
MISC: Sedation in ICU, Ventilation literature summaries

LITFL

LITFL Pulmonary Puzzle 014 — Alarmingly high pressures

FOAM and web resources

Gomersall C. ICU Web — Trouble-shooting mechanical ventilation

Critical Care

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Chris is an Intensivist and ECMO specialist at The Alfred ICU, where he is Deputy Director (Education). He is a Clinical Adjunct Associate Professor at Monash University, the Lead for the Clinician Educator Incubator programme, and a CICM First Part Examiner.

He is an internationally recognised Clinician Educator with a passion for helping clinicians learn and for improving the clinical performance of individuals and collectives. He was one of the founders of the FOAM movement (Free Open-Access Medical education) has been recognised for his contributions to education with awards from ANZICS, ANZAHPE, and ACEM.

His one great achievement is being the father of three amazing children.

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